Ocean Profile Measurements during the Seasonal Ice Zone Reconnaissance Surveys

James Morison
Polar Science Center, APL-UW
1013 NE 40th St.
Seattle, WA 98105
phone: (206) 543 1394 fax: (206) 616 3142 email: morison@apl.washington.edu

Award Number: N00014-12-1-236
http://psc.apl.washington.edu/northpole/

LONG-TERM GOALS

This grant is for the coordination of the Seasonal Ice Zone Reconnaissance Surveys (SIZRS) program of repeated ocean, ice, and atmospheric measurements across the Beaufort-Chukchi sea seasonal sea ice zone (SIZ) utilizing US Coast Guard Arctic Domain Awareness (ADA) flights of opportunity. This report covers our grant to make the ocean profile measurements across the SIZ as part of SIZRS. Our long-term goal is to track and understand the interplay among the ice, atmosphere, and ocean contributing to the rapid decline in summer ice extent that has occurred in recent years. The SIZ is the region between maximum winter sea ice extent and minimum summer sea ice extent. As such, it contains the full range of positions of the marginal ice zone (MIZ) where sea ice interacts with open water.

OBJECTIVES

The overarching objectives for SIZRS are to determine seasonal variations in air-ice-ocean characteristics across the BCSIZ extending over several years and for a variety of SIZ conditions, investigate and test hypotheses about the physical processes that occur within the BCSIZ that require data from all components of SIZRS, and improve predictive models of the SIZ through model validation and through the determination of observing system requirements.

For the ocean profiles component of SIZRS, our objective is to determine variations in ocean characteristics across the BCSIZ extending over several years and for a wide variety of SIZ conditions.

APPROACH

This grant as part of SIZRS is to deploy Aircraft eXpendable CTDs (AXCTD) and Aircraft eXpendable Current Profilers (AXCP) across the Beaufort and Chukchi Sea SIZ aboard US Coast Guard Arctic Domain Awareness (ADA) C-130 flights. The U.S. Coast Guard Arctic Domain Awareness (ADA) flights offer the way to make regular measurements over long ranges in the Beaufort and Chukchi seas at no cost for the platform. SIZRS includes a set of core measurements needed to, make complete atmosphere-ice-ocean column measurements across the SIZ, make a section of ice conditions across the SIZ, and deploy drifting buoys to give time series of surface conditions.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2012**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Ocean Profile Measurements during the Seasonal Ice Zone Reconnaissance Surveys**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Polar Science Center, APL-UW 1013 NE 40th St. Seattle, WA 98105**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**6**	

Specifically, the core elements are listed in Table 1 for the SIZRS Coordination Grant. The AXCTD and AXCP ocean profile measurements of this grant are illustrated in Figure 1.

ADA flights are conducted twice per month from March through November. On ADA flights, we will conduct atmosphere-ice-ocean observations at least once per month. These will include lines of about 5 stations across the SIZ with profile measurements through the complete air-ice-ocean column (Fig. 1).

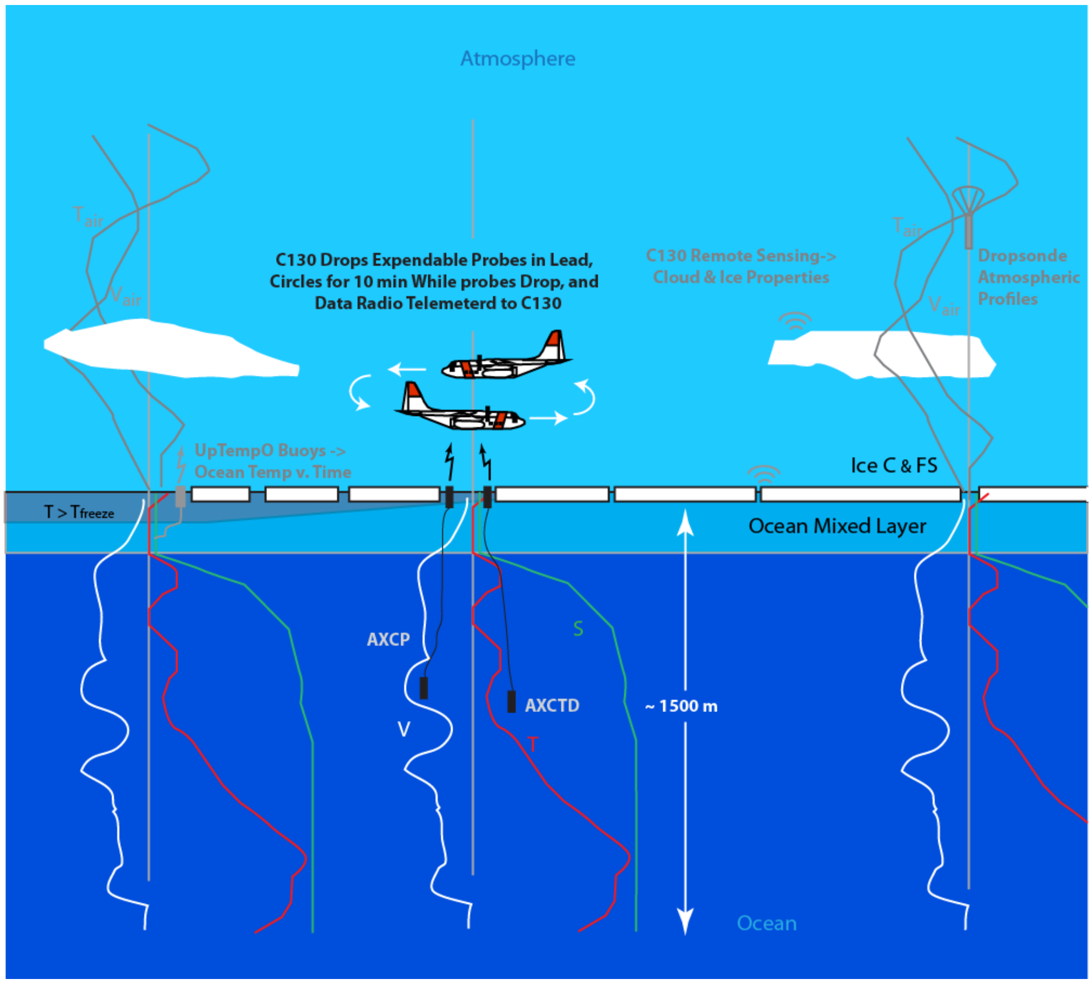

Figure 1. Schematic of the SIZRS ocean column AXCTD & AXCP profiles. Stations will be made in five locations across the SIZ (3 shown) with at least one each in open water, MIZ, and pack ice. Buoys will provide upper ocean time series at several locations. The aircraft remote sensing will measure ice & cloud properties.

Several times each season we will repeat station locations along a frequently studied longitude line (e.g., 140°W or 150 °W). Other stations will be made to examine particularly active regions of ice retreat or advance.

We have used the AXCTDs successfully in prior surveys, primarily from smaller aircraft. We have developed the method for dropping the Sippican-TSK AXCTD from C-130 aircraft during one test mission with the Alaska Air National Guard Search and Rescue Squadron in Anchorage, Alaska and with three Coast Guard ADA flights, one on September 30, 2009 (Figs. 2 and 8), one on May 25, 2010

(Fig. 6), and one during a buoy deployment flight Oct. 26, 2010. In addition to the Sippican-TSK (Tsurumi-Seiki) AXCTD expendable probes, the equipment includes a TSK AXCTD TS-RX100W Receiver (Ch.14), a T.S.K. AXCTD TS-MK150N Converter, a Marantz PMD-660 Solid State Sound Recorder, and a Macintosh laptop computer (Fig. 8).

During an AXCTD deployment, once the aircraft nears the nominal station location, we search for an open lead at least 100 m wide and free of newly formed ice. The aircraft flies down the lead at an altitude of 60-120 m, and the AXCTD is deployed by hand from the side "paratrooper" door or the open rear ramp. It parachutes to the lead surface, a float inflates on contact with water and after a short delay, the CTD probe drops from the float unit. Data is transmitted from the probe to the buoy via an ~1500-m copper wire spooled from the probe and the float. While the aircraft circles at 100 to 300 m, the data is transmitted from the float to the aircraft as 172 MHz FM radio signal (channel 14). It is received by the T.S.K. TS-RX100W through one of the standard aircraft VHF antennas. The raw reception is converted to engineering units by the TSK Converter and recorded on the laptop computer. A backup recording of the raw received signal is made with the solid state sound recorder. Based on comparison among AXCTD drops and surface CTD stations we find AXCTD are accurate to 0.02 psu and 0.02°C [*McPhee et al.,* 2009]. For each of the three years of this SIZRS grant we anticipate making AXCTD drops at 5 stations on each of 6 monthly flights plus up to five (2 in first year) UpTempO buoy deployment sites for a total of 35 (32 in first year) AXCTDs per year.

We have been using expendable current profilers (XCP) as part of the NPEO and Switchyard surveys and analyzing their data as part of our NSF Arctic Ocean Mixing Grant (http://psc.apl.washington.edu/northpole/Mixing.html). The XCP use a surface float and dropped probe similar to the AXCTD arrangement described above. We have not used the aircraft deployed version (AXCP), but our collaborator on our NSF Ocean Mixing grant, Eric D'Asaro, has used them extensively from Air Force "Hurricane Hunter" C-130s, and our XCP radio uplink receiver and recording equipment are essentially the same as the equipment to be used in the AXCP application. Our present lightweight NPEO equipment includes an ICOM IC-R20 receiver set to 172 MHz wide-band FM and a Marantz PMD-660 Solid State Sound Recorder. In the SIZRS application, we will use the same manual deployment through the paratrooper door for the AXCP that we use for the AXCTD. At each station, the two types of probe will be dropped nearly simultaneously. We will use the same aircraft VHF antenna through a splitter to feed both receivers, and we will use AXCP transmitting at 170.5 MHZ (Channel 12) to allow simultaneous radio reception and recording of AXCTD and AXCP. The raw AXCP transmission recorded on the Marantz recorder will be played back through a sound card to a laptop computer with XCP processing software developed here at the UW Applied Physics Laboratory by John Dunlap for the inventor of the XCP, Tom Sanford. Dunlap has developed a special Arctic version of the software, which is better suited than the standard Sippican deck units to the high geomagnetic latitude and commonly weak velocity shear of the Arctic Ocean. The raw audio frequency AXCP transmission will be recorded on the solid state recorder as a backup. For each of the three years of this SIZRS grant we anticipate making AXCP drops at 5 stations on each of 6 monthly flights plus five (2 in first year) UpTempO buoy deployment sites for a total of 35 (32 in first year) AXCPs per year.

WORK COMPLETED

SIZRS has nearly completed its first season working with USCG Air Station Kodiak. The coordination effort has assembled and submitted documentation needed for USCG approval of all the UW SIZRS instruments to be used on the ADA flights including the AXCTD and AXCP (Morison). So far, only the AXCTD system and the AXIB buoy of the IABP (Ignatius Rigor) are approved by the USCG for operation from the ADA aircraft, but we anticipate being informed of any Safety of Flight Test (SOFT) requirements for the AXCP soon. The SOFT is performed with a USCG C-130 on the ground at the USCGAS Kodiak ramp. The aircraft is run on the ground and all engine instruments and avionics readings are recorded. The test is repeated with all scientific gear connected as needed to the aircraft antennas and receiving and recording data. The SOFT is successful if the aircraft engine instruments and avionics instruments are not affected by the operation of the science equipment.

We have acquired all the necessary receiving and recording equipment for the AXCTD and AXCP operation, and these are ready to be used in a SOFT as soon as the Coast Guard gives us directions to do so. We have also acquired the first 35 of each kind of probe and these have been sent to USCG Air Station Kodiak for deployment. Because the AXCTD system had a prior approval, as discussed below, we have been able to use most of the 2012 AXCTD on ADA flights this year.

Using the AXCTD system we have conducted 5 SIZRS flights so far. These were on May 29, June 26, July 24, Aug. 21, and Sept. 18. All flights were made along 150°W. During the May, June, and July flights, AXCTD stations were made at 72°N, 73°N, 74°N, and 76°N. In these flights (e.g., Fig. 2) at least some sea ice was encountered at all stations and presented the challenge of finding ice free leads into which we could drop the expendable probes. By the time of the August and September flight, se ice extent was near or at a record minimum extent and the ice edge was near 80N, 150°W, so we changed the station locations to 74° N, 76°, 78°N, and 80°N. The number of stations had to be reduced and operations streamlined to allow the flights to reach the ice edge and be completed under the USCG regulation 12-hour maximum flight time.

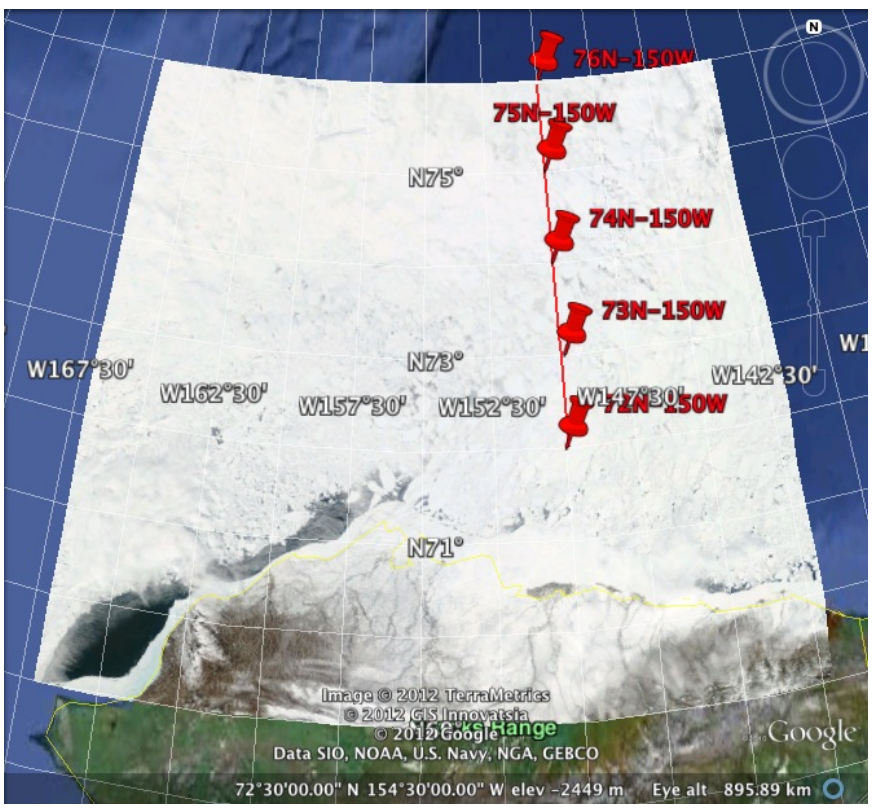

Figure 2. MODIS sea ice image for May 29, 2012 and SIZRS AXCTD stations.

RESULTS

This summer, the sea extent reached a new record minimum. Some of the seeds for this dramatic reduction extent, which occurred predominantly in the Canada Basin, are apparent in the ocean results of SIZRS from as early as our first flight in May. Figure 3a contrasts salinity sections along 150°W made May 29 and Sept 18, 2012. Figure 3b shows temperature departures from the salinity and depth determined freezing point along the same sections. Analyses of these data are just beginning, but a couple of things are immediately apparent.

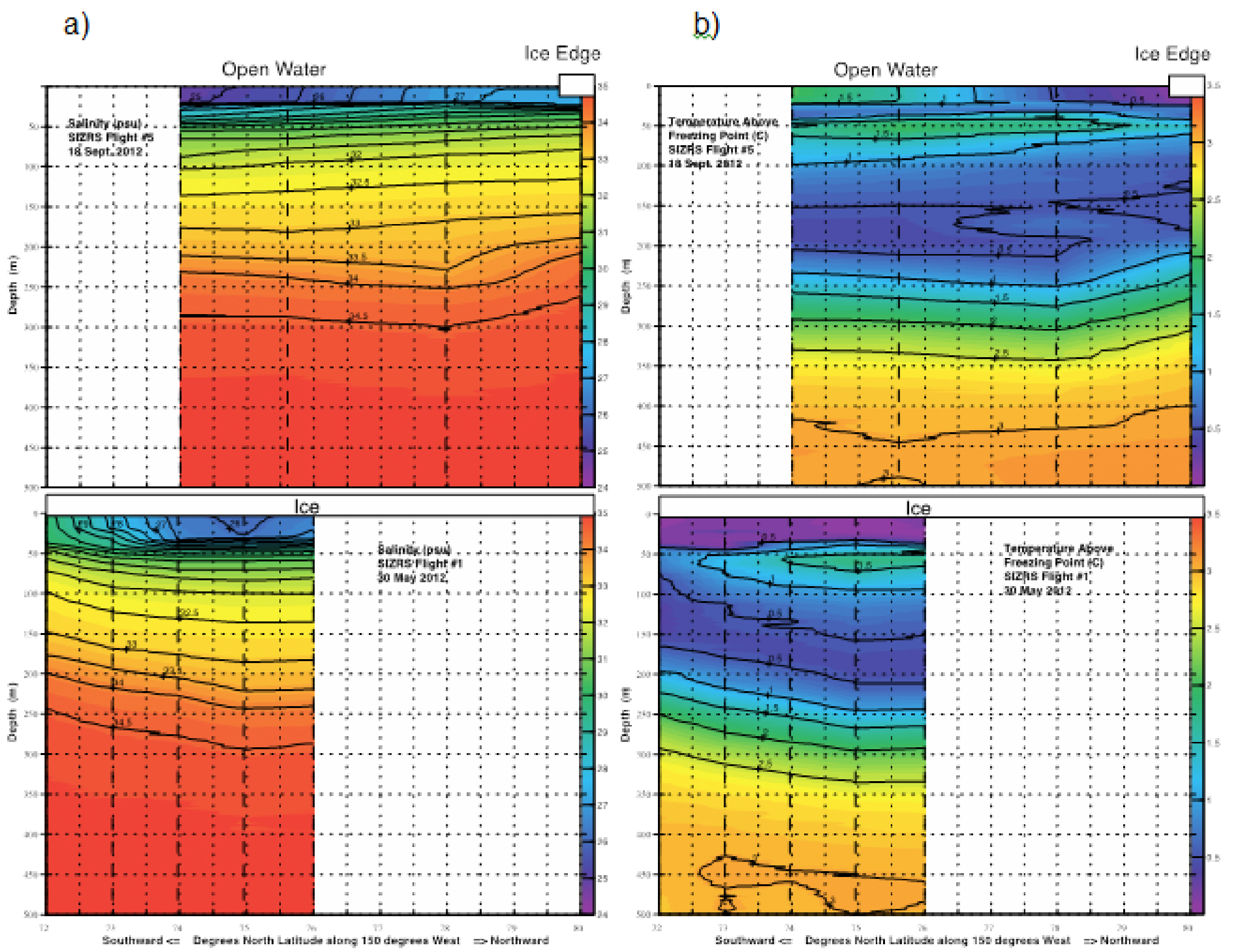

Figure 3. Salinity (a) and temperature departure (b) from the salinity and pressure determined freezing point along SIZRS sections from (bottom) May 29 and (top) September 18, 2012. Station locations are indicated by vertical dashed lines. Contours extend to 500 m depth but the profiles typically approach 1000 m. As illustrated by the white bars at the top of the figures, the section was almost completely ice covered in May and except north of 79°N it was virtually ice free.

In May, under the ice, a pool of low salinity (~26 psu) surface water in the upper 30-40 m is centered at about 76°N (Fig. 3a, bottom). In September, the layer in the same region is slightly fresher (~25-26 psu) and thinner (~ 20 m) (Fig. 3a, top). These changes are consistent with the positive buoyancy flux downward due to melting of the ice and the input of runoff over the summer. However, in recent years we have become accustomed to anomalously great anticyclonic wind stress in the summer, which has tended to cause convergence of surface fresh water, dome the sea surface, and increase depth of the constant salinity surfaces in the middle of the Beaufort Sea. In September 2012, we see that, at least above about 200 m, the isohalines have bowed upward, especially compared to May (Fig. 3a). This and the shoaling of the surface layer may be associated with the exceptionally strong cyclonic storm that dominated the Beaufort Sea in early August. Cyclonic wind forcing causes divergence in the upper ocean, consistent in this case with upward deflection of the upper ocean salinity surfaces and drift of the ice away from the center of the Beaufort Sea.

The freezing point immediately under the ice in the May section (Fig 3b, bottom) was close to the freezing point consistent with ice formation over the previous winter. Heat put into the mixed layer locally the previous summer did not remain through the winter. However, immediately below the surface layer centered at 75°N lies a 50 to 70 m thick lens of water 1.5°C above the freezing point. This is likely summer Bering Sea Water (sBSW). We speculate, that heat entrained from this warm water into the mixed layer may be responsible for the ice conditions we observed during the May and June flights. The ice cover was more solid and air temperatures were colder at the southern stations, 72°N and 73°N, than at the northernmost stations, a pattern that seemed opposite to what we expected. We speculate that together, the warm lens and the cyclonic storm event may explain why during the summer the ice pack seemed to separate around 74-75°N, with an isolated patch drifting southwest into the Chukchi Sea and the greater part moving north as part of the main ice edge. The September section (Fig. 3b, top) shows the warm sBSW lens extending north to 79°N. Comparison of May and September shows the increase in mixed layer temperature to 1.5°C above the freezing point between 74°N and 77°N. This was likely due to the input of solar radiation absent ice cover over the summer. Mixed layer temperatures remain near the freezing point in the ice edge region, consistent with our observation of some thin ice formation at the 80°N site in September.

IMPACT/APPLICATIONS

The SIZRS effort is a pioneering program in the use of aircraft expendable ocean and atmosphere sensor probes in tracking changes in the sea-ice environment of the Arctic. It will lead to greater availability of synoptic snapshots of environmental properties over extended ranges.

RELATED PROJECTS

See Table 1 of the report for “Seasonal Ice Zone Reconnaissance Surveys”, grant number: N00014-12-1-0231.